Evolution of the Space Insurance Market

THESIS

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Abstract

As the width and breadth of space travel expands and evolves, so do the associated risks. From the perspective of risk management, it is important for insurance companies to have a good understanding of the current and future state of the space industry, and to devise an appropriate process for creating insurance products meant for space travel. With the recent attempts by private organizations to send civilians into space, insurance companies must account for the different variables that impact risk. The primary issue faced by these underwriters is the lack of substantial historical data to reference when designing their insurance packages. The challenge posed to space insurance underwriters is the limited number of manned and unmanned launches since the beginning of modern space exploration. With the clear limitations in relevant data, underwriters likely must look to the most relatable forms of insurance as a means of setting some standard upon which they will build the foundation for the space insurance market. The research conducted seeks to use data from the National Transportation Safety Board's (NTSB) Aviation Accident Reports on manned aviation and aerospace accidents over the past several decades. These reports include information about the nature of each accident as well as the NTSB's conclusions as to the probable causes of the incidents. Cross examining each incident with its probable causes and resulting damages allows for a better understanding of the primary factors involved in aviation and aerospace accidents. As the data shows, several commonalities existed amongst the accidents; including pilot error, aircraft malfunctions, inadequate company and compliance standards, and deficiencies in FAA regulations. Extrapolating these findings in the context of space travel serves to illustrate how insurance underwriters would go about assessing the risks associated with manned space exploration, and the inputs they would use to develop policies.

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Major Fields: Business Administration / Actuarial Sciences

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Introduction

Background

On April 12, 1961, Yuri Gagarin became the first man in human history to travel into space. At the time, the idea of putting men and women into orbit was a distant dream, far beyond the capabilities of the science and technological capabilities of the time. Yet as the space race of the Cold War era escalated, the thought of space exploration become more and more realistic. For most of the world's history in space travel, the primary driver behind the research and funding came from government programs like NASA. Fast forward fifty years into the future, and we can see that the landscape is beginning to evolve. With companies like SpaceX and Virgin Galactic investing resources towards space travel, it is apparent that space is becoming increasingly commercialized. As such, this change presents new challenges across the board.

The research being conducted will focus on one challenge in particular; the evolution of the space insurance market. For most of the history of space travel and exploration, government programs have been the primary force in developing the industry. Entities such as NASA and Roscosmos are the governmental bodies responsible for space science programs of the United States and Russia respectively. As a result, any space missions designed by these governments have been self-insured. With the practice of space-travel becoming more commercialized, private companies are beginning to explore the possibilities of putting people into space. Not backed by any particular government, these companies must seek insurance for their endeavors from standard insurance companies.

The research seeks to understand how underwriters go about assessing the risks of sending private, manned space crafts into space and seeing how this process compares to the

standard insurance practices for automobiles and aviation. In essence, the research looks to determine what inputs go into the insuring of the newly privatized enterprise and how the space insurance market will evolve as a result of this.

Overarching Problem

The primary issue faced by these underwriters is the lack of substantial historical data to go off of when designing their insurance packages. With only limited number of manned and unmanned launches since the beginning of modern space exploration, underwriters must likely look to the most relatable forms of insurance as a means of setting some standard upon which they will build the foundation for the space insurance market.

Research Question

The research question that this paper seeks to answer is what inputs go into the underwriting process for the insurance of private, manned space crafts? With that primary question in mind, the objective of this research will be to see if there is a method by which underwriters can standardize the process of insuring private space travel without having the benefit of having historical data. It will also look to assess the similarities and differences between this new insurance market and the existing and well established markets, such as automobiles and aviation insurance.

Hypothesis

The introduction of the human element into private space travel will make the underwriting process resemble that of aviation insurance. When insuring an aircraft, the factors to be considered are the type of vehicle, the safety standards of the vehicle, and the type of driver using the vehicle. In a similar sense, the type of space craft, the quality of its production, and the experience and background of the space travelers will likely act as major inputs for underwriters trying to insure individuals and private organizations looking to go to space.

Literature Review

With the primary objective in mind, it is important to understand that much of the findings will build off of the existing research into the evolution of the space insurance industry as a result of commercialization and privatization. Further examining the current state of the industry will in turn help to guide the research towards achieving the stated objectives while not retreading that which is already understood about the topic.

A good place to set a baseline for what is already understood about the industry comes from the Federal Aviation Administration. In a Quarterly Launch Report published by the administration, the relevant parties seek to discuss launch results from the third quarter of the year and launch forecasts for the fourth quarter of the year and beyond. While more recent reports are present, the fourth quarter of 2002 was the most recent to review the space and launch insurance industry. It examines the industry as a whole, changes in the industry, and also looks at the outlook for space insurance. The primary benefit of a report from 2002 is that it allows for a comparison to be made between the projected state of the industry and the actual state of the space insurance market as of 2016. Because space commercialization is more of a recently growing trend, it will be interesting to see what risks were anticipated at the time of the publication, and whether or not they are being addressed in the present time.

Research articles published in the journal Acta Astronautica are also a good source of information that pertain to the state of space insurance and how the introduction of private, manned space crafts will impact the underwriting processes for assessing the associated risks. For instance, in a piece written by Denis Bensoussan in 2010, the author looks at the space insurance industry from a commercial perspective. The author acknowledges the growing

commercialization of the space industry and seeks to examine how this new element affects the underwriting process. In particular, the lens through which Bensoussan looks through is that of space tourism. This blends several insurance practices and policies because the tourism aspect means that both man and machine must be taken into account during the underwriting process. In turn, more risk management questions have arisen that must be considered for the future. Another relevant research article comes from Ana Cristina Van Oijhuizen Galhego Rosa. The author of a 2013 piece writes more about the human element of space travel, and how it adds several complications to the insurance practices for the relevant market. Similar to Denis Bensoussan's piece on space tourism, this article focuses on the changing nature of the market as a result of its commercialization. In particular, the author examines the possibilities of new premiums, policies, and insurance products related to human space travel. For the purpose of the research, this provides more insight into how insurance companies can go about standardizing the methodology of insuring space travel. By detailing these insurance products in a manner similar to those that currently exist for auto and aviation insurance, the underwriting process can be further standardized.

For the purpose of actually collecting data for the research, the most appropriate method would be to emulate the practices and procedures of existing researchers. Examining a piece written by Piotr Manikowski and Mary A. Weiss in 2012 offers a reasonable template that can be used to proceed with the research. The authors seek to shed light on the ambiguity associated with the ever changing space insurance market. In particular, they try to investigate the cyclical nature of the market and to formally assess its volatility. By looking at the space insurance market in this manner, the authors are able to quantify the unknowns inherently associated with space insurance. For the purpose of the research, this article offers viable insight into how

underwriters are taking past data to try and standardize the underwriting processes and practices of space insurance. In comparison to other articles examined, this looks exclusively at satellite insurance, which may be easier to underwrite and model based on historical data as it does not have the added risk of human space travel.

Methodology

Data Collection

The primary methodology for collecting pertinent information for the research will be to examine historical data. Because of the inherently limited historical data on space launches, comparable information will be collected to draw comparisons and conclusions. The research conducted by Manikowski and Weiss serves as a basis for data collection, as it looks at the historical trends of satellite launches and sought to measure the volatility of that specific portion of the space insurance market. To extend the data beyond unmanned space crafts and add the crucial human element, the research will look to examine the insurance practices and procedures for aviation. The primary assumption in this data collection method is that there are enough similarities between aviation and aerospace to warrant assessing if the underlying risk factors are comparable. With space exploration still considered to be in its infancy as an industry, collecting comparative data from related fields appears to be the most reasonable and realistic method of going about the research.

For the purposes of developing a cohesive dataset, the National Transportation Safety Board's (NTSB) Aviation Accident Reports will be used as a means of compiling relevant information on manned aviation and aerospace accidents over the past several decades. These reports include relevant information about the nature of each accident as well as the NTSB's conclusions as to the probable causes of the incidents. Cross examining each incident with the likely causes will allow for a better understanding of the primary factors involved in aviation and aerospace accidents. Extrapolating these findings in the context of space travel will serve to

illustrate how insurance underwriters would go about assessing the risks associated with manned space exploration and the inputs they would use to develop policies.

While the NTSB has accident data from the past several decades, a timeframe of 1996 to 2016 was chosen for data collection. By looking exclusively at the most recent aviation incidents, the data will best replicate the potential issues that would face the aerospace industry. While the aerospace industry is in a state of infancy, it utilizes advanced technologies that would be most closely replicated by modern aviation. With the timeframe in mind, 100 incidents were recorded and analyzed for certain characteristics. In particular, the points of interest for each accident were the date of occurrence, number of casualties, the status of the aircraft, and the NTSB's assessment of probable cause.

Data Analysis

After the raw data was collected, each incident was scrubbed to derive a common set of characteristics for the probable causes. These set of common underlying factors found in Table 1 served as the basis for analyzing the relevant inputs for aerospace insurance. As per the corresponding table, the seven most frequent risk factors were; Pilot Error, Aircraft Malfunction, Failure to Follow Protocol, Inadequate Compliance Standards, Inadequate Company Standards, Insufficient FAA Oversight, and Weather. What follows is a brief description for each variable, indicative of how the NTSB's probable causes were categorized.

I. **Pilot Error:** Any physical or psychological impairment affecting the judgement and decision-making skills of the pilot.

II. **Aircraft Malfunction:** Defects in the construction or maintenance of the aircraft.

III. **Failure to Follow Protocol:** Decisions made specifically by the flight crewmembers to break standard and emergency protocols set in place for takeoff, in-flight complications and landing.

IV. **Inadequate Compliance Standards:** Indicative of instances in which substandard industry-wide protocol results in an accident.

V. **Inadequate Company Standards:** Indicative of instances in which actions by the company sponsoring the flight, manufacturing the aircraft, or training the flight crew directly influenced the accident.

VI. **Insufficient FAA Oversight:** Instances in which the Federal Aviation Administration (FAA) failed to oversee the advancement, safety and regulation of civil aviation as per its defined mission statement.

VII. **Weather:** Indicative of inclement weather resulting in incident

Upon identifying the overarching commonalities amongst the accidents, each underlying factor was then measured against the severity of the accident. Severity was measured in two forms, number of casualties and status of aircraft. Doing so gives a more complete picture of how the underlying factors would influence life, property and casualty insurance. Determining which factors were more prevalent than others in terms of causing human casualties and damage to the aircraft would help to narrow down the list of variables into those most viable as input metrics for the space insurance market.

Another factor considered for analysis was that of time. It was important to see if there was any change in the accident causes as time progressed over the past two decades. The primary reason for doing was to eliminate the chance that any of the identified risk variables were no longer prevalent in the aviation industry and therefore would not be a probable cause in the aerospace industry. Also examined was how the concentration of each factor changed as the aviation industry evolved and matured. Doing so would offer insight into what kinds of risk metrics would be more concerning for a relatively new industry like that of aerospace and how those metrics could change over time if following the same trajectory as the aviation industry.

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Figure 1: Primary Causes for Aviation Incidents

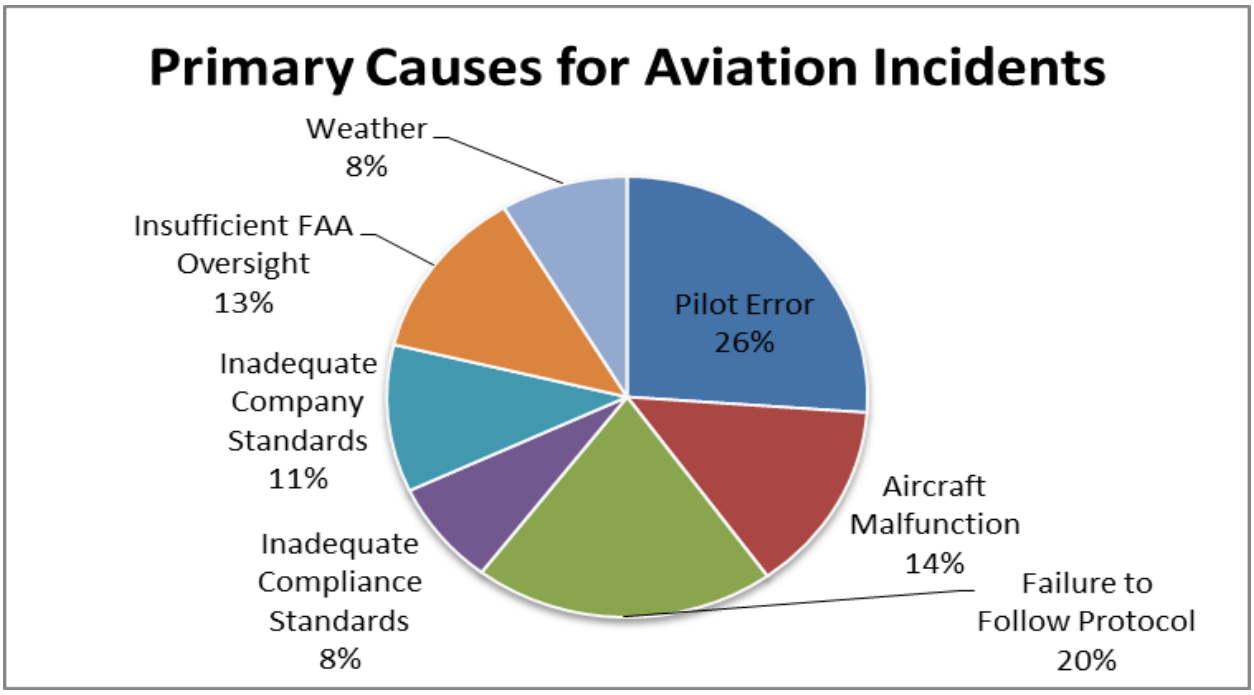
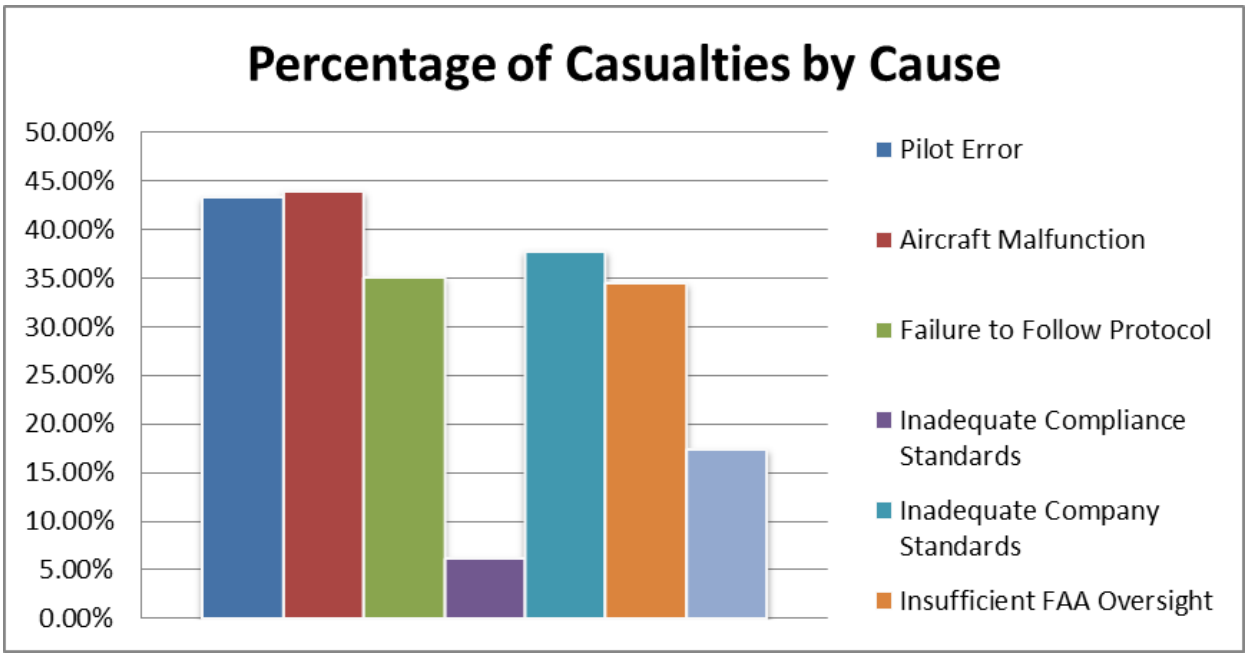
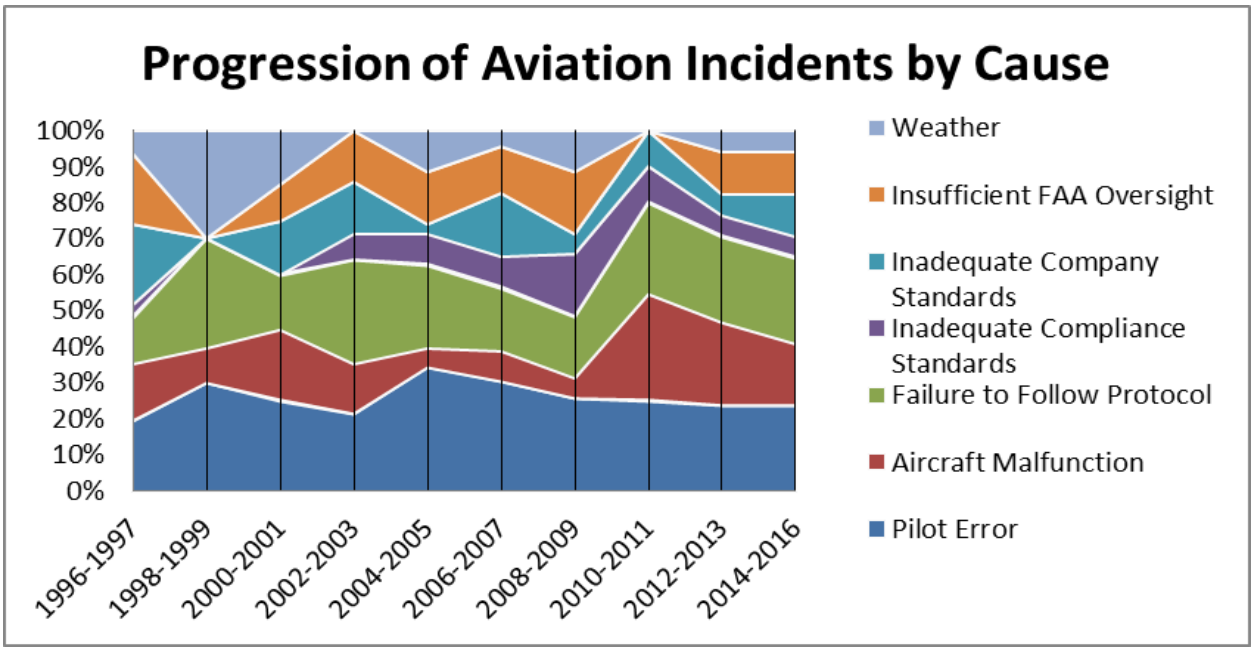


Figure 2: Percentage of Casualties by Cause



*More than one factor resulted in each incident

Figure 3: Progression of Aviation Incidents by Cause



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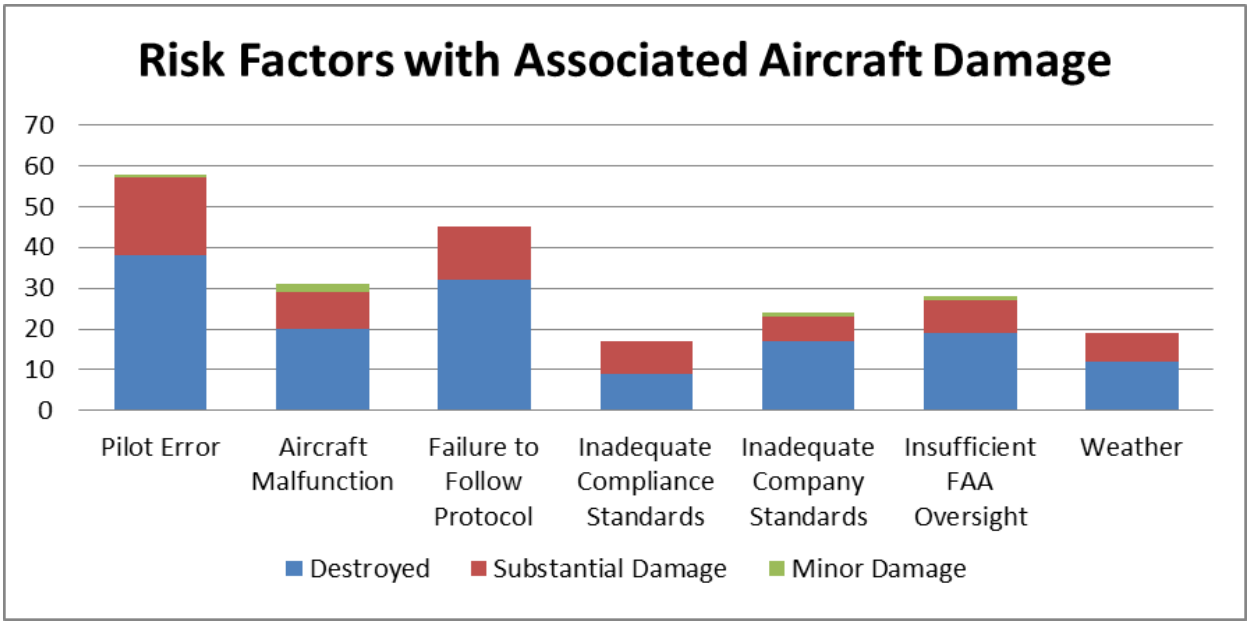

*More than one factor resulted in each incident

Results

Primary Causes for Aviation Incidents

With the seven common risk factors clearly defined, the next course of action was to determine the prevalence of each cause over the two decade time period. Figure 1 illustrates this by showing which risk factors occurred with the highest frequency. As per the pie chart, the top three causes for aviation incidents were pilot error, aircraft malfunctions and a failure to follow protocol. At first glance, there appears to be a relatively even distribution between the variables, indicating parity in the significance of each factor. However on further inspection, it can be noted that the three primary reasons pertain more to human and mechanical error than to issues specific to the aviation industry.

Percentage of Casualties by Cause

Figure 2 takes a closer look at how the defined variables relate to the number of casualties recorded over the two recorded decades. In particular, the graph measures the percentage of deaths as a result of each underlying risk factor. Percentages were used to better display the data as most accidents had more than one probable cause. As such, the graph shows that the top three factors contributing to human casualties were aircraft malfunction, pilot error, and inadequate company standards. While the addition of company standards deviates from the results of the previous graph, it is worth noting that human and mechanical error clearly resulted in the most number of casualties from 1996 to 2016.

Progression of Aviation Incidents by Cause

With Figure 3, the intention was to determine how the concentration of each underlying cause changed over the course of the twenty observed years. Displayed as a stacked line graph, the figure shows the fluctuation of the risk factors to better understand if there is any noticeable increasing or decreasing trends, spikes, or other anomalies. The most consistent causes over the time period were pilot error and failure to follow protocol. This further reinforces the idea that human error (whether related to the pilot or the crewmembers) is a consistent and highly consequential risk affecting the aviation industry. Another noteworthy observation is the gradual decline in aircraft malfunctions before a spike around 2008-2010. A reasonable explanation for this shift is that the drastic increase in malfunctions coincided with aircraft components reaching the end of their effectiveness and not being inspected and replaced.

Risk Factors with Associated Aircraft Damage

The purpose of Figure 4 is to determine the severity of each risk factor using a different metric – the status of the aircraft after the accident. With three possible results, the stacked bar graph illustrates not only which cause resulted in the most amounts of damage, but also how severe the damage to the aircraft each factor was. This graph continues the trend of highlighting pilot error, failure to follow protocol, and aircraft malfunction as the most prominent risk factors affecting the aviation industry. This appears to hold true whether the aircraft was completely destroyed, substantially damaged, or only sustained minor damage.

Conclusions

Whereas most relevant literature has determined that not enough historical data exists to make any reasonable conclusions about how the commercialization of aerospace would influence the development and evolution of the space insurance industry, the research conducted sought to take a more proactive approach. Without the benefit of historical data, the research looked for comparable insurance industries to see if there are any underlying factors that can serve as viable input metrics for assessing potential risks in the space insurance industry.

Upon analyzing the results of the compiled aviation incidents it appears reasonable to extrapolate the input measures for risk assessment from aviation to aerospace. This is because the primary causes for the incidents can be attributed to human error and physical defects with the actual aircraft. The data confirms the initial hypothesis because the most frequent and most severe risks in the aviation industry were not specific to just that industry. This means that space insurance underwriters can reasonably look to these metrics when assessing risk, even without any historical data to back it up.

Taking this a step further, to measure these risks in the aerospace industry, underwriters would follow similar processes to that of the aviation industry. For instance, considering the significance of pilot and crewmember error, the physical and psychological conditioning of the entire flight crew would likely need to be assessed to gauge flight-readiness. Along those lines, the quality of training and years of relatable experience for the pilot and flight crew should be used to further evaluate risk. Aside from the human element, underwriters would also need to look at the aircraft itself. In particular, the quality and construction of the aircraft being deployed would need to be examined and assessed in an effort to mitigate the likelihood of mechanical malfunctions resulting in an accident.

Implications/Future Research

The fundamental purpose of the research is to establish a platform upon which the space insurance market can build off of. Rather than having to wait for aerospace accident data to become available, the research seeks to take a more proactive approach to establishing the basis for the new insurance market. As space travel becomes more commercialized, the need for compatible insurance packages is more apparent than ever. With companies like SpaceX planning on sending tourists around the Moon in 2018 and Boeing, Virgin Galactic and Blue Origin following suit, the once distant thought of civilians traveling to space is becoming a reality. Especially when considering that private space tourism is in such an early stage, not being able to properly insure such activities could stymie the growth of the industry.

Given the innate limitations of the current space tourism industry and associated space insurance industry, there are many more directions the current research can be taken in the future. One area yet to be explored is the actual costs associated with the new insurance packages. While the research tried to prove that the risk metrics for aviation insurance are transferable to aerospace insurance, trying to relate the costs would likely yield much different results. Determining what would eventually become the industry standard costs for these insurance packages would likely require working directly with insurance companies to understand their pricing models for existing industries.

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Appendix

Table 1: Common Underlying Risk Factors

Variable Name	Variable Description
Pilot Error	Physical or psychological impairments affecting the judgement and decision-making of the pilot
Aircraft Malfunction	Defects in the construction or maintenance of the aircraft
Failure to follow protocol	Decisions by the flight crewmembers to break protocols set in place for takeoff, in-flight complications and landing
Inadequate compliance standards	Indicative of instances in which substandard industry-wide protocol results in an accident
Inadequate company standards	Indicative of instances in which actions by the company sponsoring the flight, manufacturing the aircraft, or training the flight crew directly influenced the accident
Insufficient FAA oversight	Instances in which the Federal Aviation Administration failed to oversee the advancement, safety and regulation of civil aviation
Weather	Indicative of inclement weather resulting in incident